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Morphology of Coastal Marshes, Southern Connecticut

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MORPHOLOGY OF COASTAL MARSHES, SOUTHERN CONNECTICUT

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PALUDAL STRATIGRAPHY AND MORPHOLOGY

Introduction

There were before human intervention an estimated 43 sq. mi. of tidal marsh along the 98-mi. straight-line length of the Connecticut coast. In the last decades B.P. (before physics) some work had been done on the paludal stratigraphy and morphology, but no regional study had been attempted. Brown (1930) described a section in a now-flooded clay pit near North Haven and discussed its significance. Knight (1934) described a small marsh in Branford that "revealed a section preserving the hitherto unrecorded early stages of a New England salt marsh developed in accordance with Shaler's classic theory, coupled with later stages developed in accordance with the theory first proposed by Mudge and later reproposed and elaborated by Davis."

In 1960, encouraged by preliminary work and the reports of Brown and Knight, a systematic study of the Connecticut coastal marshes was begun by Bloom. The initial goal was to collect sufficient samples for radiocarbon dating so that the age and rate of postglacial submergence could be determined. Field work was supported in part during 1960 by the Connecticut Geological and Natural History Survey, and since 1960 by the Office of Naval Research, Project NR 388-065. Since the initial goal was achieved (Bloom and Stuiver, 1963) the project has been modified to include research on sedimentation rates and shoreline erosion of the coastal marshes.

Consideration of the relationship between sedimentation and submergence pervades the interpretation of the Connecticut coastal marsh environment. Three significant paludal environments can be distinguished, wherein the interaction of the two variables has produced three distinct stratigraphic records.

(a) *The estuarine "fresh-water" marsh.* Where a sufficiently large river enters an estuarine marsh, the fall and rise of the tide causes alternate accelerated stream flow and slack water. The salinity is low, but the nutrient content of the water is apparently high. A dense growth of *Typha* (cattail), *Phragmites* (reed), and *Scirpus* (bulrush), commonly more than 6 ft tall, characterizes this environment. Harshberger (in Nichols, 1920, p. 540) likened these marshes to the British "fens." Production and accumulation of organic debris has kept pace with submergence, and a thick layer of sedge peat has been built up to the local high-tide level in the marsh.

(b) *The former deep (9-50 ft) bay or lagoon.* During rapid submergence, until about 3,000 years ago, the sea transgressed into coastal valleys and produced bays or lagoons. In an environment of generally low wave energy and low sediment supply, early submergence exceeded the rate of sedimentation, and open water of near-normal salinity persisted in the embayments. However, during the last 3,000 years submergence has been slow enough to be equaled by the sedimentation rate, and salt marshes have filled former bays and lagoons. A typical stratigraphic section of these salt marshes is composed of a veneer of muddy salt-marsh peat, 9 ft or less in thickness, overlying a thick wedge of mud that has an open-bay fauna. Below the mud in many marshes there is a thin layer of sedge peat in sharp contact with the substratum. This peat represents the fringe of "fresh-water" rushes and reeds that grew at the transgressing shoreline.

(c) *The shallow (less than 9 ft) coastal marsh.* A coastal embayment less than 9 ft deep below present high-tide level was not affected by submergence prior to 3,000 years ago. Many of the shallow marshes are on submerged coastal lowlands, especially outwash plains, which continue their gentle seaward slope up to a mile beyond the high-water line. Many of these low-relief areas were marshy even before submergence raised the water table. The vegetation on these marshes is zoned landward from salt marsh through belts of progressively lower salinity tolerance to either normal upland vegetation or fresh-water marsh. The stratigraphy of a shallow marsh is similar to that of the upper 9 ft of a salt marsh in a former deep bay, except that lenses and tongues of sedge peat complexly alternate with salt-marsh peat. The alternations reflect shifts of vegetation belts across the marsh as seasons of abnormal high tides or excessive fresh-water runoff displaced the zone of salt marsh respectively landward or seaward. Deeper parts of the marsh apparently represent former topographic basins that filled with sedge peat as a result of the rising ground-water table prior to marine inundation. A normal upland soil profile on glacial drift commonly underlies a shallow coastal marsh.

Three marshes (fig. 1) have been chosen to represent the three paludal environments outlined.

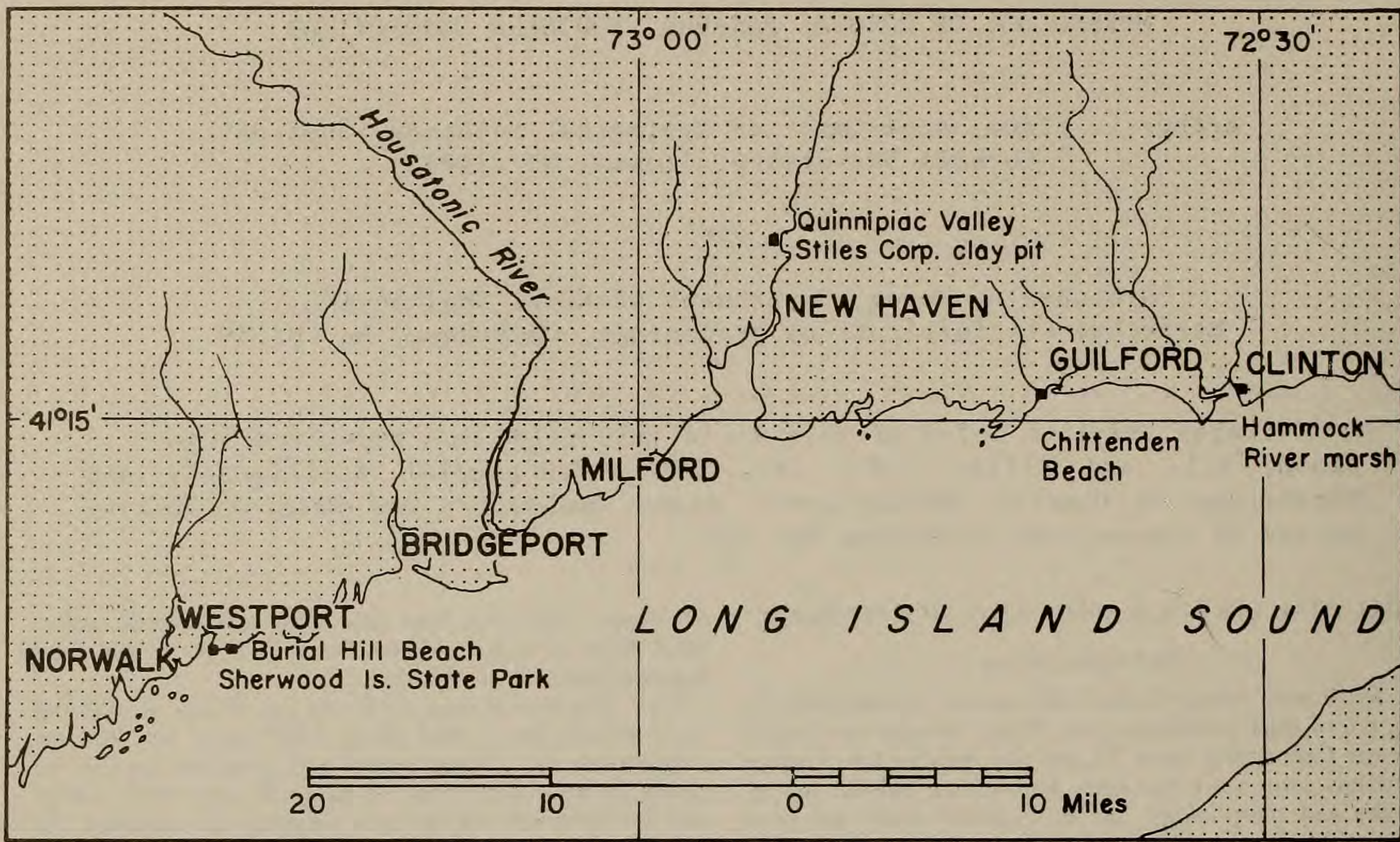

Fig. 1. Index map of the central Connecticut coast

Quinnipiac Valley, Hamden — an estuarine "fresh-water" marsh

Excellent exposures of late-glacial and postglacial deposits have been available for many years in the brickyard clay pits of the Quinnipiac Valley, near New Haven. The section described by Brown (1930, p. 263-266) was obtained from a now-flooded pit north of the Stiles Corporation brickyard. However, a similar section (fig. 2) is currently exposed in the pit south of the brickyard.

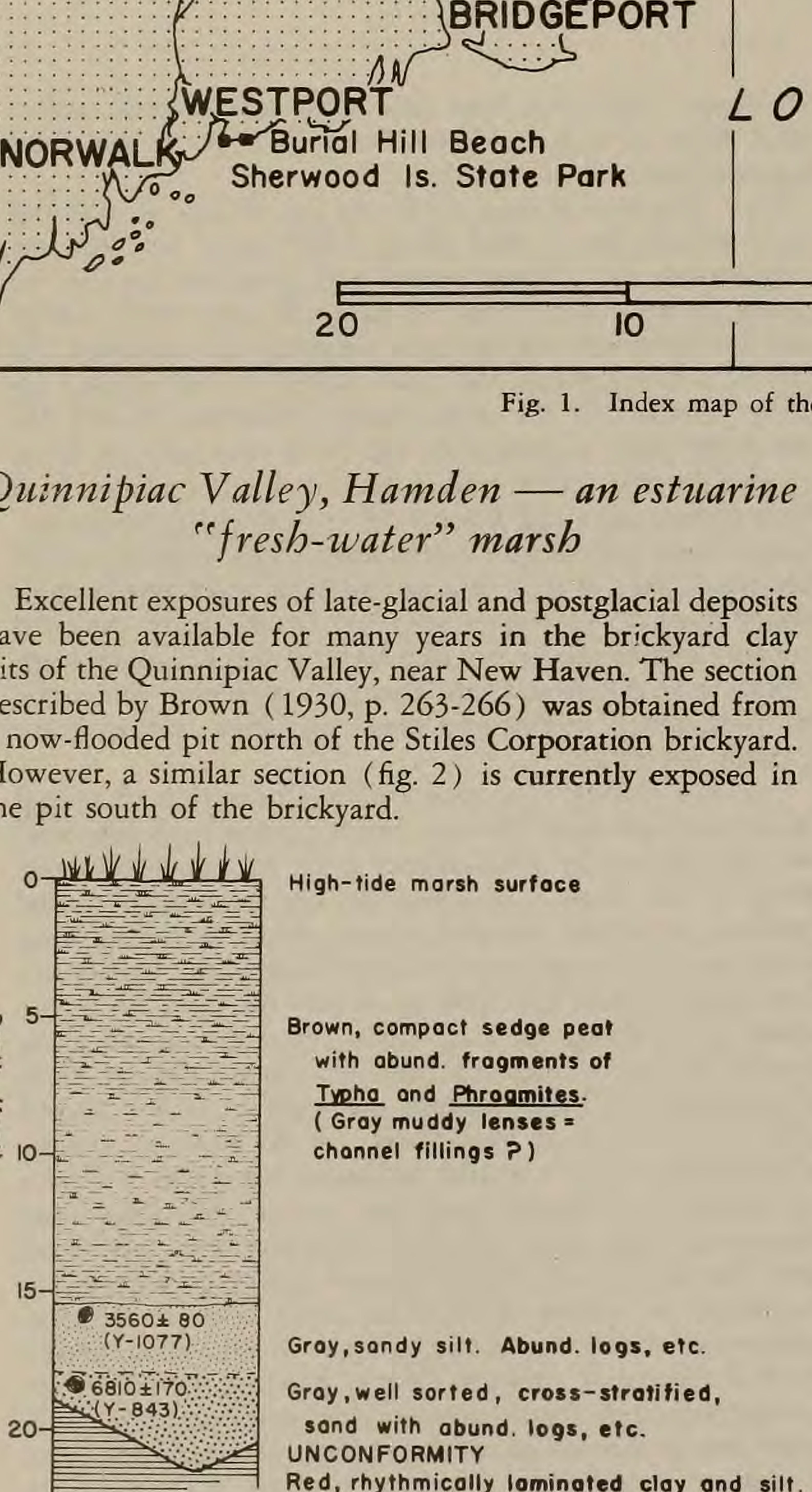

Fig. 2. Generalized stratigraphy of the Stiles Corporation clay pit, Hamden, Connecticut

The postglacial stratigraphy of the Quinnipiac Valley begins at the erosional unconformity between underlying glacial deposits and overlying alluvium. An episode of stream erosion to a lower-than-present base level followed deposition of the late-glacial lacustrine New Haven Clay. Erosion was followed or accompanied by fluviatile deposition of cross-stratified sand and gravel. In other parts of the Quinnipiac Valley yellowish-gray outwash unconformably overlies the channeled upper surface of the New Haven Clay (Porter, 1960, p. 18). The alluvium in the Stiles clay pit is not outwash, as is evidenced by (1) the arkosic composition of the alluvium, (2) the dominantly hardwood composition of the enclosed logs and leaf mats, and (3) a radiocarbon age of 6810 ± 170 years B.P. for a log from the alluvium (Y-843). Postglacial erosion in the southern end of the Quinnipiac Valley apparently not only removed the outwash that formed the final glacial deposit of the valley, but cut into the underlying reddish, arkose-derived ice-contact stratified drift and lacustrine clay and silt. This unconformity represents a hiatus of approximately 6,000-7,000 years prior to 6800 B.P.

The basal alluvium of the postglacial section exposed in the Stiles Corporation clay pit grades upward into gray sandy silt of questionable origin. The silt represents the loss of former stream transporting power. It is a slack-water deposit but whether it is a fresh-, brackish-, or salt-water deposit has not been determined. Foraminifera or sponge spicules are not present. The silt contains abundant logs, twigs, nuts, and leaf trash of species similar to those preserved in the underlying alluvium. A log from the top of the silt was radiocarbon dated at 3560 ± 80 years B.P. (Y-1077).

Brown sedge peat, 12 to 17 ft thick and similar to that which is presently accumulating on the marsh surface, immediately overlies the silt. The nature of the contact indicates an abrupt change in the depositional environment from the time of silt accumulation to the time of peat accumulation, although no erosional unconformity is apparent. Old reports (Davis, 1913, p. 700; Brown, 1930, p. 265) described a "forest soil" and tree stumps rooted in place beneath the peat of the Quinnipiac Valley, but no recent observers have verified these reports. At the Stiles Corporation clay pit, the transition from silt deposition to peat accumulation represents only a change in depositional environment without an interval of weathering and soil formation. This change took place shortly after 3560 B.P. Since then, the Quinnipiac Valley has had its present appearance, with a cattail, sedge, and reed marsh growing to high-tide level in an estuarine environment of low salinity. Salt-marsh grasses do not now enter the valley in significant quantity north of the railroad yards, 2 mi. south of the clay pit.

Depth measurements on the pit face are subject to error because of compaction of the clay-pit wall by an overlying earth dike. Figure 3 shows a section through the south face of the Stiles Corporation clay pit on June 16, 1962, shortly after the earth dike had been moved back for a new cut in the pit. A shallow sag pond parallel to the outer edge of the dike and tension cracks on the inner slope indicated that compaction was in progress. The peat at boring 1 had been compressed from an original thickness of 15.7 ft to 13 ft, or to about 83 percent of its original thickness. That much compaction was accomplished by earth fill about 12 ft deep on the boring site for an estimated 2 months. At the pit face, where the dike is believed to have lain through the preceding winter, the compaction was to about 63 percent of original peat thickness. To further complicate depth measurements, some "heave" or relaxation at the site of boring 1 seemed to have resulted from the removal of the dike. Vertical faults in the New Haven Clay, parallel to the pit face and upthrown on the pit side, suggested that both compression under the load of the dike and subsequent relaxation also may take place in the underlying silt-clay rhythmites. Thus, the depths of radiocarbon-dated samples from the clay pit are not considered as reliable as those of samples collected by coring undisturbed marshes.

Hammock River Marsh, Clinton — a former deep bay or lagoon

The Hammock River marsh in Clinton (fig. 4) has the appearance and stratigraphy typical of many Connecticut salt marshes. The surface is a thick mat of short, wiry salt-marsh grasses, especially *Spartina patens.* Along the banks of channels, the taller salt thatch, *S. alterniflora,* grows. Whereas *Spartina patens* can tolerate only a brief wetting by salt water at normal high tide, *S. alterniflora* can tolerate submergence of its roots for 5 to 16 hours daily. The combined effect of these two plants and similar species has been to build and maintain the marsh surface very close to the local mean high-water level.

(A tidal gate installed under the Hammock River bridge of Route 145 now inhibits the inflow of salt water to the northeastern part of this marsh, and reeds, shrubs, and weeds are rapidly destroying the smooth beauty of the salt meadow. The southwestern arm of the salt marsh is flooded by high tides through a drainage ditch extending through Hammock Point Beach to the southwest, and has not yet degenerated.)

Prior to submergence, the Hammock River probably flowed west on a flood plain about 38 ft below the present marsh surface. A tributary valley sloped northeast toward

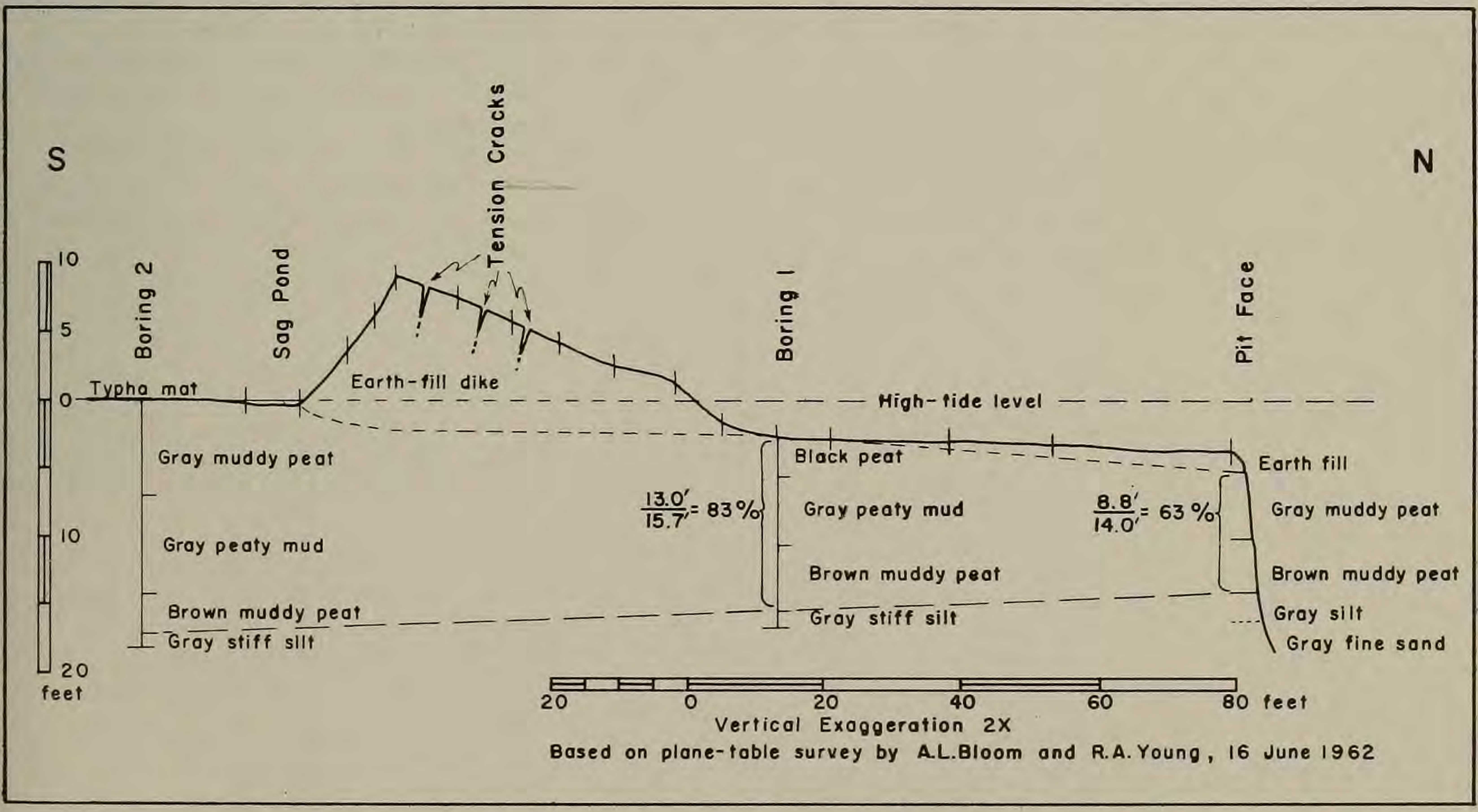

Fig. 3. Section through south face of Stiles Corporation clay pit, Hamden, Connecticut

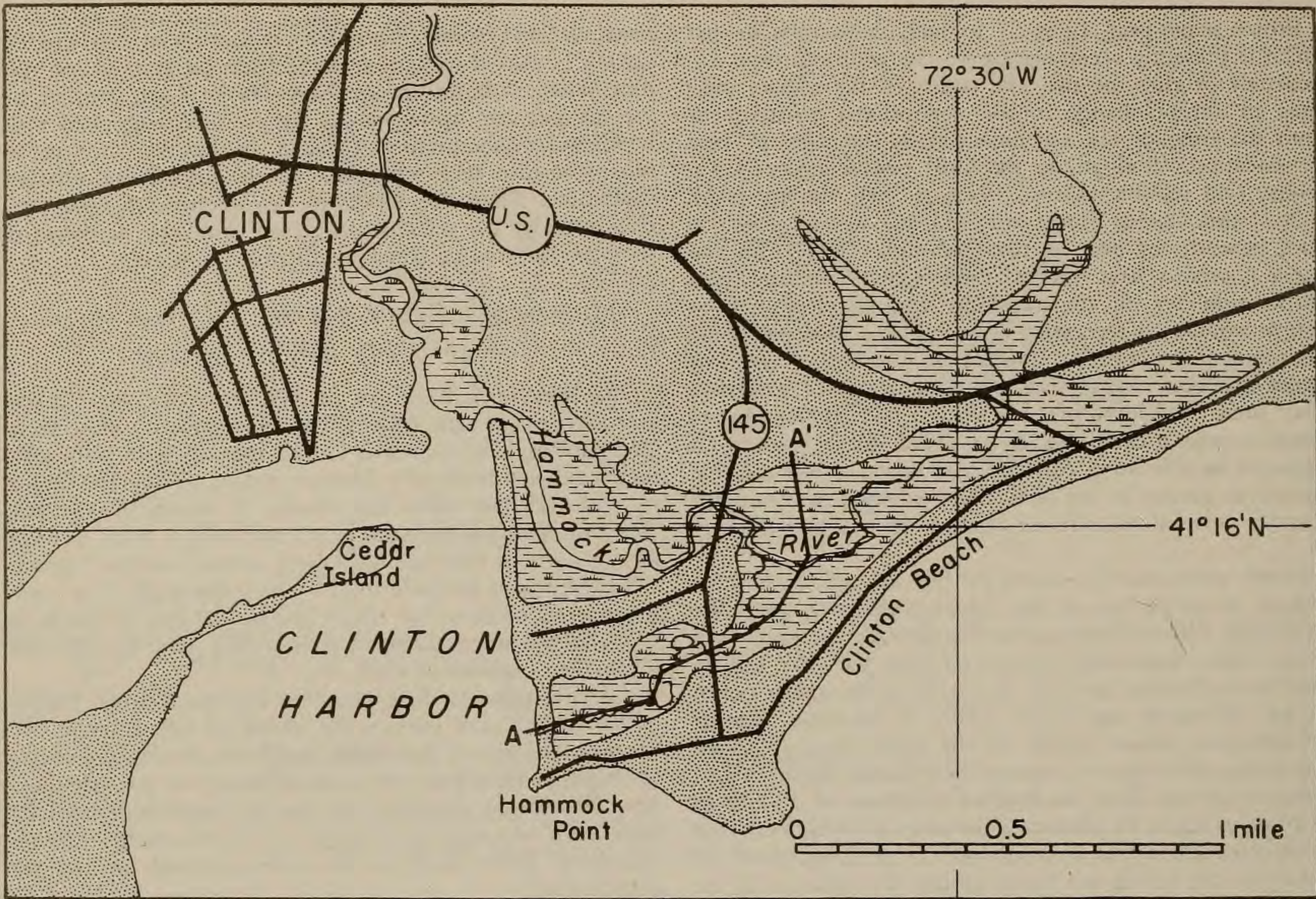

Fig. 4. Hammock River marsh and vicinity, Clinton, Connecticut

the river along line of section A-A' (fig. 4). Figure 5 shows the stratigraphy of section A-A'. The base of the section is the sand and gravel of the former valley floor, which had a northeastward gradient of about one percent.

As the sea transgressed eastward into the Hammock River valley, then southwestward into the tributary valley along the line of section, the shoreline was fringed by rushes and sedges. The basal unit of the stratigraphic section is a layer of sedge peat that accumulated at the transgressing high-tide shoreline. The sedge peat is overlain by mud of a shallow open-bay environment. The mud contains an abundant shallow-water, muddy-bottom fauna of snails, clams, and Foraminifera. Frances L. Parker (1962, personal communication) reported the following notes on the Foraminifera of boring 15 of the section:

> The upper 8 samples (8 ft.) contain a marsh fauna, either tidal marsh or shallow marsh pools. With sample 8, a rather meager bay fauna appears. I would guess that the

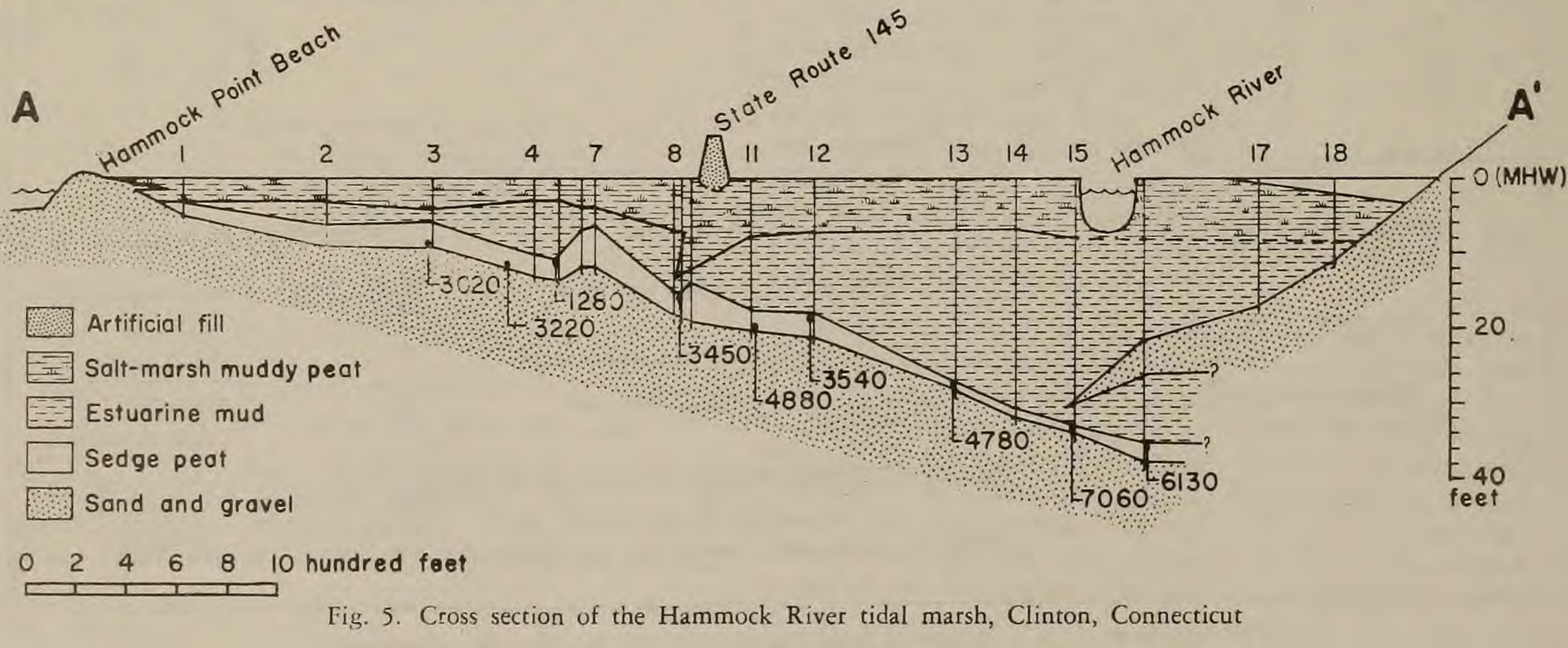

Fig. 5. Cross section of the Hammock River tidal marsh, Clinton, Connecticut

water was probably shallow and conditions not too good for the Foraminifera. In one or two samples, there was evidence of solution of the $CaCO_3$ tests. The bay fauna is best developed at about samples 12-17. By bay, I don't mean a nice big open bay but rather some kind of semi-enclosed bay, probably with salinities somewhat lower than truly marine ones.

Sedimentation in the Hammock River estuary or lagoon (the nature of the embayment and the distribution of former barriers has not been determined) did not keep pace with submergence prior to 3,000 years ago, and open-water conditions persisted. However, when the rate of submergence decreased about 3,000 years ago, mudflats built up to the mid-tide level and were populated by *Spartina alterniflora*. The mid-tide marsh that developed was an efficient sediment trap, and in a short time the marsh surface had been built to high-tide level, where *S. patens* and related species became established. The lower third of the "salt-marsh muddy peat" of figure 5 consists of strawlike *S. alterniflora* fragments in mud, whereas the upper two-thirds consists of the fibrous roots of *S. patens* and similar high-tide species. Submergence of about 9 ft during the 3,000 years of marsh formation produced the thick section of peat derived from plants that live in a narrow vertical range near high tide (the "Mudge-Davis" type of salt marsh).

The positions and radiocarbon ages of peat samples from the Hammock River marsh are shown in figure 5. Table 1 is a list of radiocarbon-dated samples from coastal Connecticut (after Bloom and Stuiver, 1963, p. 333). The dates are plotted against sample depth in figure 6 (Bloom and Stuiver, 1963, p. 333) and a curve is drawn through the samples whose depths have not been affected by compaction. The most reliable samples used in preparing the submergence curve came from the base of the sedge peat in the Hammock River marsh, where a nearly ideal combination of permeable substratum and sloping valley floor permitted the accumulation of sedge peat only very near the high-water shoreline of the transgressing sea. The depth of these samples below the present high-tide marsh surface in the same embayment is an accurate measure of the relative change of level since peat accumulation began. Samples collected from the top of the buried sedge-peat bed plot below the curve of submergence by an amount equal to the compaction of the peat. The displacement by compaction plus the present thickness of peat equals the original thickness, and the ratio of present to original thickness can be calculated. The sedge-peat bed beneath the Hammock River marsh has been compacted to between 13 and 44 percent of orignial thickness. Older and deeper samples (6,130 yrs. = 22 percent; 4,780 yrs. = 13 percent) show greater compaction.

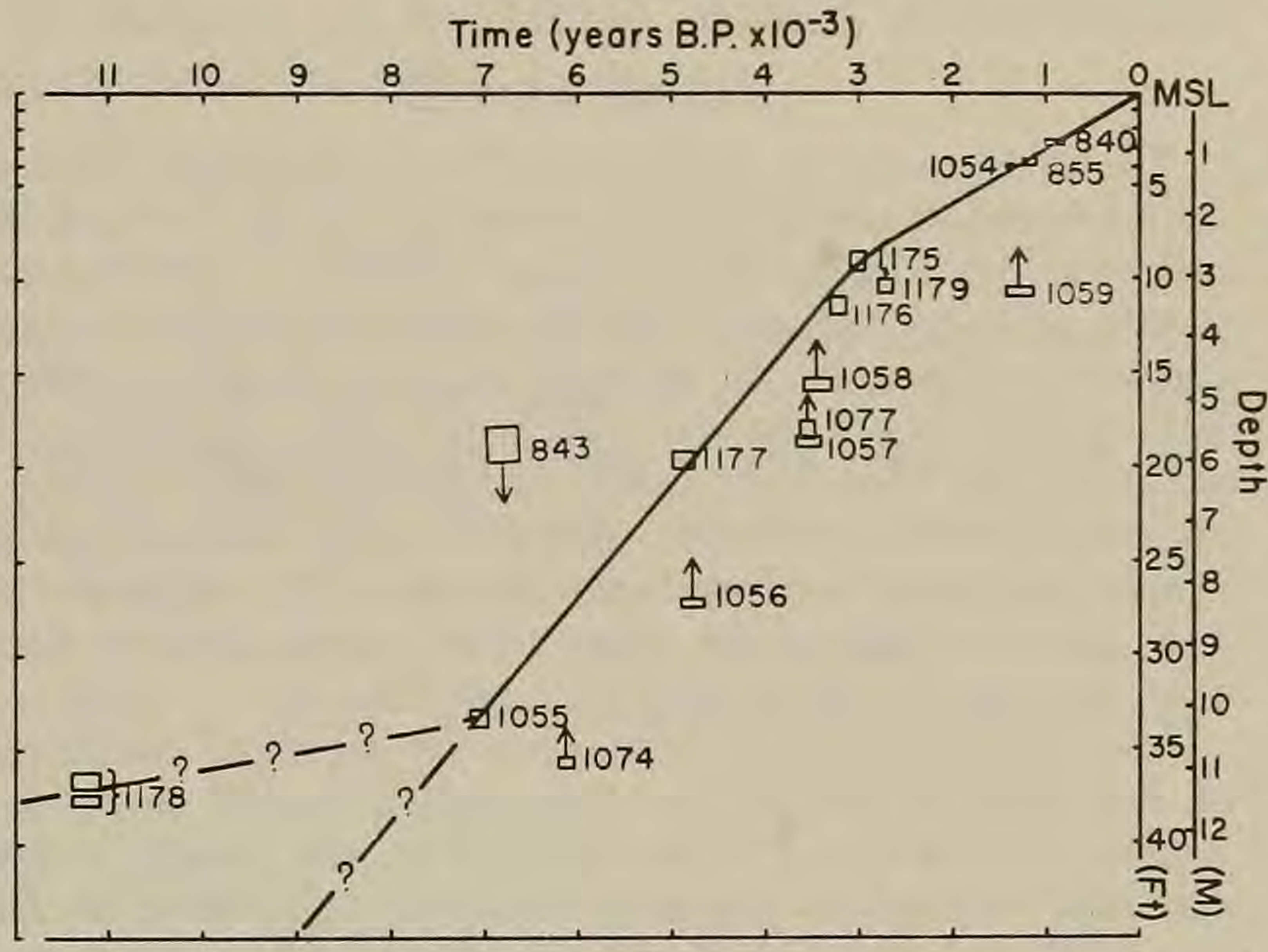

Fig. 6. Submergence of the Connecticut coast (Bloom and Stuiver, 1963). The line is the locus of a point now at mean sea level.

Table 1. Radiocarbon-dated samples from coastal Connecticut[1]

Laboratory No.	Locality	Sample	Depth (ft)	Age (years before present)
Y-840[2]	Branford	Cedar root	2.7 ± 0.2	910 ± 120
Y-843	North Haven	Log	18.5 ± 1.0	6,810 ± 170
Y-855[2]	Guilford	Oak log	3.8 ± 0.2	1,180 ± 80
Y-1054[2]	East Norwalk	Tree root	4.0 ± 0.2	1,400 ± 70
Y-1055[2]	Clinton	Peaty sand	33.3 ± 0.4	7,060 ± 100
Y-1056	Clinton	Sedge peat	27.2 ± 0.3	4,780 ± 130
Y-1057	Clinton	Sedge peat	18.6 ± 0.3	3,540 ± 130
Y-1058	Clinton	Sedge peat	15.6 ± 0.3	3,450 ± 160
Y-1059	Clinton	Sedge peat	10.7 ± 0.3	1,280 ± 150
Y-1074	Clinton	Sedge peat	35.7 ± 0.4	6,130 ± 90
Y-1077	North Haven	Log	18.0 ± 0.5	3,560 ± 80
Y-1175[2]	Clinton	Sedge peat	9.1 ± 0.6	3,020 ± 90
Y-1176[2]	Clinton	Sedge peat	11.4 ± 0.5	3,220 ± 90
Y-1177[2]	Clinton	Wood and bark	19.6 ± 0.5	4,880 ± 120
Y-1178[2]	Clinton	Sedge peat (combined)	36.6 ± 0.5 37.7 ± 0.3	11,240 ± 160
Y-1179	Westport	Sedge peat	10.4 ± 0.4	2,710 ± 90

[1] Bloom and Stuiver, 1963, p. 333

[2] Samples whose depth range does not require correction because of compaction

Chittenden Beach, Guilford — a shallow coastal marsh

The small marsh at the back of Chittenden Beach formed on an outwash plain. The outwash appears to be thin, as numerous bedrock knobs protrude through it. The smooth profile offshore indicates that the outwash plain formerly extended at least a mile seaward of the present shoreline. Whether or not a barrier beach formerly protected the marsh has not been determined. The present beach is undernourished, and is little more than a fringe of sand and shells being "bulldozed" landward over the marsh by storm waves. The marsh in back of the eastern part of the beach is now only about half as wide as it was in 1960.

It is possible that the marsh formerly extended thousands of feet seaward, and at its outer edge a barrier beach extended from headland to headland. If so, the present marsh and beach remnants represent the final stage of landward retreat of a barrier beach across a filled lagoon. However, development of this marsh may not have been the result of a protecting barrier. Former glacial deposits, now submerged or eroded, may have provided protection for the early marsh. In that case, the present beach is only a reworked remnant of drift, rather than of a former barrier beach. As a third possibility, it may be that no more protection has ever been provided for this marsh than it now has. Erosional retreat of the marsh edge has been at the rate of 10 ft or more per year since 1960, and at least 2 to 3 ft per year during recent decades, according to local residents; however, these rates may not be typical of erosional retreat during the several thousand years of marsh history. The widespread destruction of eel-grass beds offshore in the early 1930s may have exposed this shoreline to more rapid erosion. Late spring storms of the past two years have been responsible in large part for the recent erosion, but their frequency in the past has not been investigated in this study. Furthermore, the submergence of the New York City tide gauge between 1893 and 1953 averaged 0.011 ft per year (Disney, 1955), about four times the average rate of submergence in Connecticut of 0.3 ft per century through the last 3,000 years. If submergence has accelerated in the past century, the effects would be most noticeable on exposed peat shorelines such as Chittenden Beach.

Some indications of a change in shoreline development at Chittenden Beach appeared in 1963. Formerly, the wave-cut intertidal peat cliff fronted on a barren tidal flat, but in 1963 a heavy growth of *Spartina alterniflora* covered much of the flat. If this vegetation persists, it may trap enough sediment from the river mouth and offshore to rebuild the marsh to high-tide level, leaving the present beach as a "chenier" across the marsh. Future years will determine the validity of this hypothesis.

The stratigraphy of Chittenden Beach marsh has been studied by coring, and is also exposed in the wave-cut cliff at low tide. The pollen profile of a 270 cm (9 ft) core from a site now beneath the beach was prepared by Sears (1963, p. 59). Figure 7 is reproduced from his report. The oxidized peat zone at the base of the section probably represents chemical activity by ground water from the underlying drift, but it could have paleoclimatic significance. The transition from underlying sedge peat to overlying salt-marsh peat was 95 cm (3.1 ft) below the marsh surface. The arboreal pollen content of the core shows a general shift upward from oak to pine and hemlock. Sears (1963,

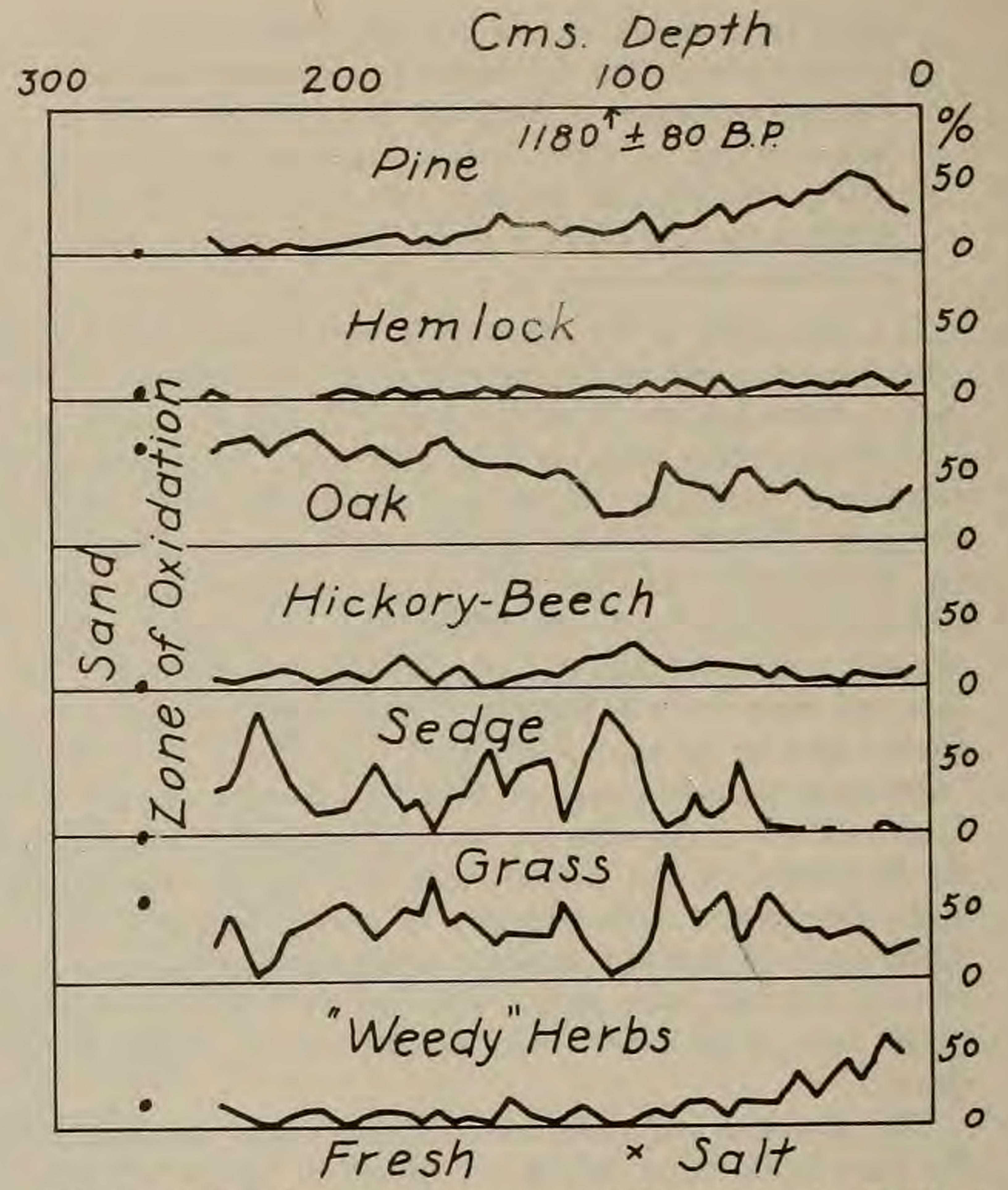

Fig. 7. Pollen diagram of important indicators in the Guilford, Connecticut, coastal marsh (Sears, 1963)

p. 59) interpreted this as a trend toward a cooler and moister climate during the time of marsh accumulation. Superimposed on the climatic change inferred from the arboreal pollen are a series of reciprocal alternations between sedge and grass pollen. Sears (1963, p. 59) interpreted these recurrent fluctuations as showing a pulsating rather than steady rise of the water table during submergence on the hypothesis that "slight rises in the water table normally favor sedges at the expense of grasses." However, in coastal marshes salt-marsh grasses normally displace sedges during growing seasons of abnormally high tides, the reverse of Sears' hypothesis. Most of the sedge-to-grass fluctuations are recorded in the sedge-peat part of the core, but some are shown in the upper salt-marsh peat as well. Because the environment has been in delicate balance with several variables, climatic interpretation is not easy.

In the wave-cut cliff of peat, sedge peat is interbedded with salt-marsh muddy peat. The best indicator of accumulation in a low-salinity marsh is the distinctive curved-triangular culm of *Scirpus maritimus,* the common coastal bulrush. Fibrous, wiry mats of roots represent growth of *Spartina patens* and related high-salinity salt-marsh plants. An oak log from the base of the wave-cut bank at Chittenden Beach was 1,180 ± 80 years old (Y-855). It came from a layer of black "fresh-water" peat 115 cm (3.8 ft) below present high tide, nearly at the contact with underlying sand.

Shoreline Erosion at Chittenden Beach, Guilford

The shore zone of Chittenden Beach was plane-table surveyed at a scale of 1:240 (1 inch = 20 feet) in 1964, 1965, 1973, and 1983 (Bloom, 1967; Harrison, 1975; Young, 1985). The maps are too large for reproduction in the guidebook, but will be available during the excursion. In 1965, the most extensive recent erosion along the Connecticut coast was measured at Chittenden Beach, Guilford and at the Chaffinch Island shore immediately west of Chittenden Beach across the mouth of West River. From aerial photographs, the measured erosion at the center of the Chittenden Beach marsh had been 55 m between 1949 and 1965. Most of the erosion took place before the summer of 1962.

During the "Great Atlantic Storm" of March, 1962, the sand beach ridge at Chittenden Beach was thrown back onto the marsh surface 15 to 30 m behind a wave-cut peat bank in the intertidal zone. Compaction has lowered the overridden peat so that high spring tides still reach the foot of the beach ridge, but in general the beach became isolated from a sand supply and could be called a "chenier". By 1965, the small tidal marsh behind Chittenden Beach had been narrowed to half its 1960 width by beach retreat. Erosion of the marsh edge may have been accelerated when the sucession of hurricanes between 1954 and 1960 pushed the beach excessively far inland and left the marsh exposed. Inadequate sediment supply has subsequently prevented a new protective beach from forming. Chittenden Beach is obviously undernourished (Bloom, 1967).

In the relatively storm-free decade prior to 1973, new growth of <u>S. alterniflora</u> added 4000 m^2 to the marsh area in the central part of Chittenden Beach, while 800 m^2 was eroded from the eastern and western margins (Harrison, 1975). The former wave-cut peat bank of the central beach became almost buried by new sediment trapped on the foreshore by <u>S. alterniflora</u>.

The 1983 survey showed several meters of progradation at the east end of the beach, where erosion had been dominant prevously. By contrast, the central beach area had retreated 10 to 20 m, and a new wave-cut scarp had formed. The pre-1965 scarp between the lower and higher levels of <u>S. alterniflora</u> marsh was no longer continuous, due to erosion on the upper marsh or possibly vertical accretion on the lower marsh surface in the previous decade. The western end of the shore zone had retreated more than any other part, by up to 20 m (Young, 1985). The west end of Chittenden Beach had been a river-side wharf in the last century, and stone-filled log cribbing had progressively protruded into the bay along the edge of West River as the beach eroded. Since 1973 the remnants of the old structure have been largely destroyed, but the mounds of cobbles are still obvious.

After disappointing attempts in the early 1960's to convert Chittenden Beach into a recreational swimming area, the citizens of Guilford wisely dedicated the area for classes in nature study and shoreline biology. With this enlightened outlook, they can watch future changes with interest rather than concern.

Vertical Accretion at Hammock River March, Clinton

Beginning in the summer of 1962, immediately after the major storm in March of that year, marker beds of about 1 m^2 were established on six selected Connecticut coastal marshes. Various materials have been used, but the most sucessful is the variously colored decorative "glitter" that is readily available in variety stores and stationers. Annual increments of glitter in contrasting colors were added to the marker beds from 1962 through 1966 (Bloom, 1967). The annual vertical accretion of mud on the marsh surface is recorded by measuring the average separation of successive layers of glitter. Most of the sites were relocated and refurbished in 1973 and 1974 by Harrison (1975) and again in 1983 by Young (1985). Young (1985) also resurveyed 12 similar marker beds on the shores of Long Island that had been established in 1974-1976. Her results are summarized in Table 1.

On the Hammock River marsh in Clinton (Figure 4, p. C-7-4) two marker beds were established in 1962. Both are near the bank of the Hammock River but one (Hammock River east) is upstream of a tidal gate under the bridge at State Route 145, and the other (Hammock River west) is downsteam. The tidal gate is a "flapper" type, designed to open on a falling tide and drain the eastern part of the marsh, but to close on a rising tide and prevent most of the tidal flooding. Some tide water enters the eastern part of the marsh through drainage ditches that cross the marsh from the southwest, but full high-tide flooding is prevented unless the river gate is intentionally opened. As a result of the restricted tidal flooding, the former high-tide salt marsh east of the road was rapidly invaded by brackish-water plants, including Phragmites reed, upland weeds, and woody shrubs. West of the tidal gate the salt-marsh vegetation is a normal S. patens and Distichlis association.

The Hammock River west marker bed was established in 1962 on an area of marsh that probably had been burned within the previous year. No decaying grass matted the surface of the mud. Vigorous new grass sprouted from the firm, level mud surface. When the 1963 marker layer of coal was spread, the 1962 layer was covered with only 1 to 2 mm of mud, plus some decaying grass debris that was not included in the thickness measurements (Figure 7).

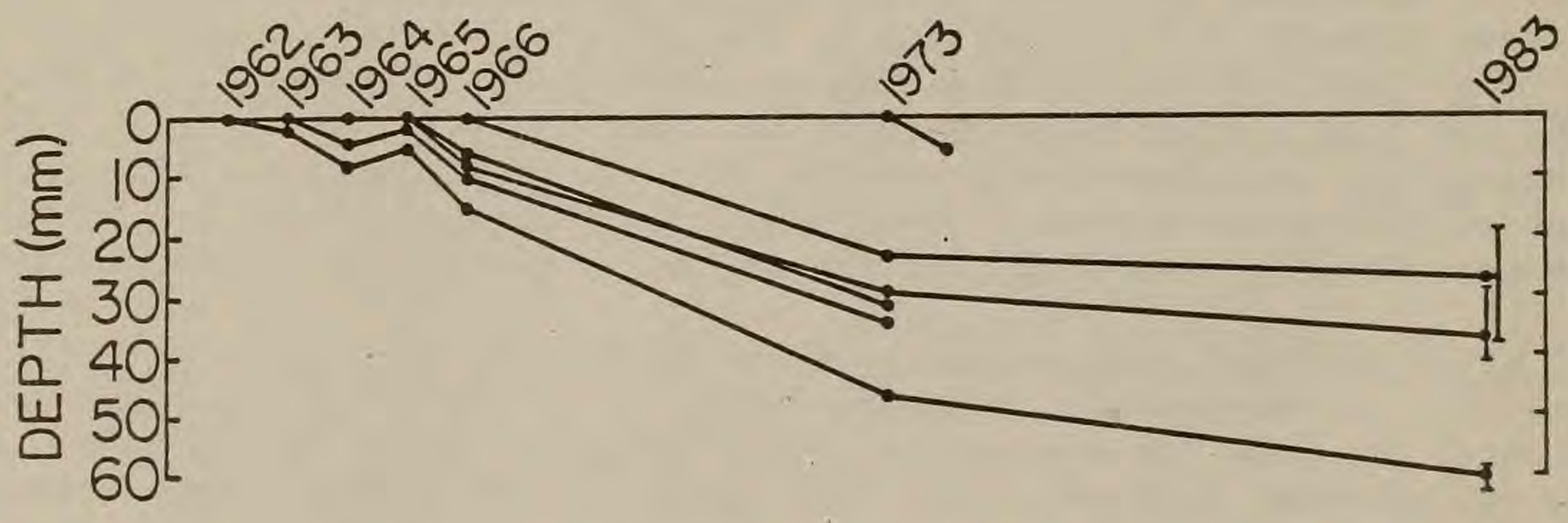

Figure 7. Vertical accretion, Hammock River west. (Young, 1985, Fig. 29).

TABLE 1

Site	Vegetation	Sed. Rate (mm/year)	Length of Record (years)
Connecticut Sites			
Barn Island	Sp	1.7	21
Great Island	Sp	4.8	11
Hammock River	Sp	2.3	21
Stony Creek	Sas	6.7	20
Nells Island	Sp	4.8	20
North Shore Long Island			
Flax Pond	Sp	1.5	2
Wading River	Sp	4.6	7
Mattituck Inlet	Sas	3.8	9
Eastern Bays			
Orient Point	Sas	0.5	2
Cedar Beach Point	Sas	1.5	2
Birch Creek	Sp	2.4	7
Squire Pond	Sp	2.5	9
Clam Island	Sp	1.8	9
Acabonack Harbor	Sp	1.9	9
Napeague Harbor			
South Shore			
Shinnecock Res.	Sp	4.5	2
Westhampton Beach	Sp	3.0	9
Carmans River	Sp	4.6	9

Sas = *Spartina alterniflora*, short (dwarf)

Sp = *Spartina patens*

The marker bed lost some sediment bvetween 1964 and 1965. In 1965, gold glitter from 1964 was widely exposed at the mud surface beneath rotting grass, and coal of the 1963 layer, which was buried in 1964, was again exposed over part of the marked bed. Blue glitter from 1962, which had been found to a depth of 7 mm in 1964, was found only 3 mm below the surface of 1965. It must be emphasized that the measurements of Figure 7 are based on only a few turf samples cut from various parts of the marker bed, and may include some anomalies caused by microrelief at the mud surface.

In 1966, all four previous years' layers were found and measured in three turf samples. In addition to the mud accumulation recorded in Figure 7, about 25 mm of loose rotting humus covered the marker bed area. The grass had fully recovered from the pre-1962 burn. Without defining terms, the Hammock River west is subjectively regarded as a "typical" Conecticut high-tide marsh. Accumulation averaged 4 mm per year between 1962 and 1966 (Bloom, 1967). After 1966, the decade intervals of restudy preclude any siginificant statement about shorter term fluctuations in accretion rates. In 1983, the 1962 marker bed and two younger horizons were relocated, and the average accretaion rate for 21 years was determined to be 2.3 mm/year (Young, 1985).

Hammock River east (Figure 8) is building upward at an exceptional rate. The cause is primarily the rapid accumulation of organic debris from reeds and shrubs that are invading the eastern, fresher area of the marsh upstream of the tidal gate.

Local residents reported that the tidal gate was fastened open during the 1964-65 and 1965-66 winters, and the eastern marsh was flooded and covered with a sheet of ice during much of the winter. Winter flooding and ice-rafted sediment may contribute to the exceptional sedimentation rate in the eastern part of the marsh, and yet not inhibit the summer growth of upland annual weeds and shrubs. Some pebbles and coarse sand were collected near the eastern marker bed. Ice rafting or human transport are the only plausible explanation for such coarse material in the center of a large tidal marsh.

By 1966 an extensive portion of a former creek channel in the Hammock River east marsh was completely filled and marked only by a slightly wetter meandering trace of unusually bright green grass. The eastern part of the main Hammock River channel was also filling with sediment. Steep, undercut river banks in 1962 had become gentle, muddy slopes by 1966, on which *S. alterniflora* was pioneering. Large areas of this marsh changed from salt-marsh grass to dense thickets of reeds and shrubs within a few years. The increasing fire hazard in this drying marsh is of great local concern. The average vertical accertion rate (Figure 8) was about 17 mm per year from 1963 to 1973 (Harrison and Bloom, 1977). In 1983 the reference stakes for this bed could not be relocated, and the vegetation, channel configuration and nearby references for compass bearings had changed so much that this interesting and anomalous marker bed was lost.

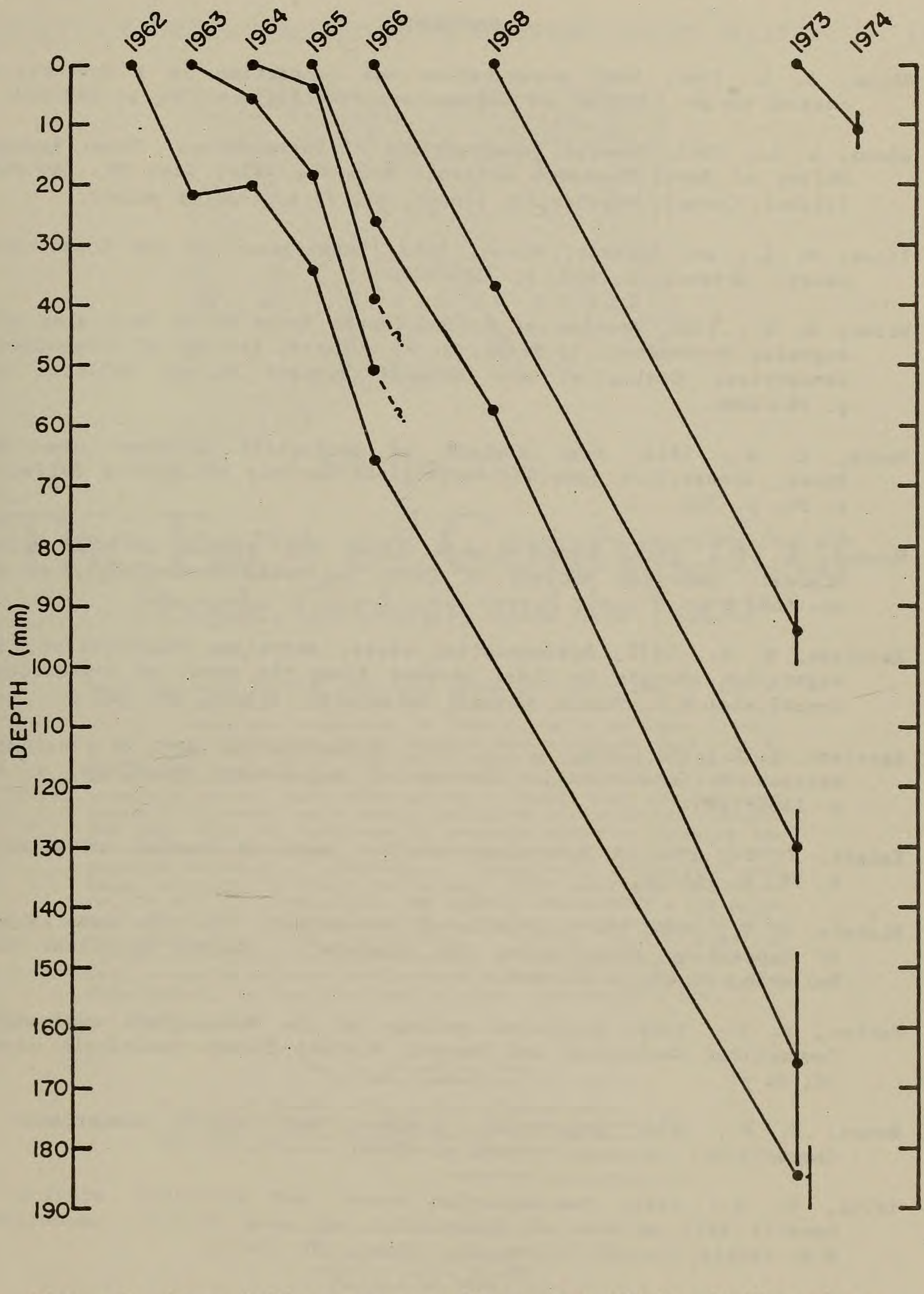

Figure 8. Hammock River east - sediment accumulation in Phragmites communis. To minimize disturbance only the 1973 horizon was recovered in 1974 (Harrison, and Bloom, 1977, Fig. 9).

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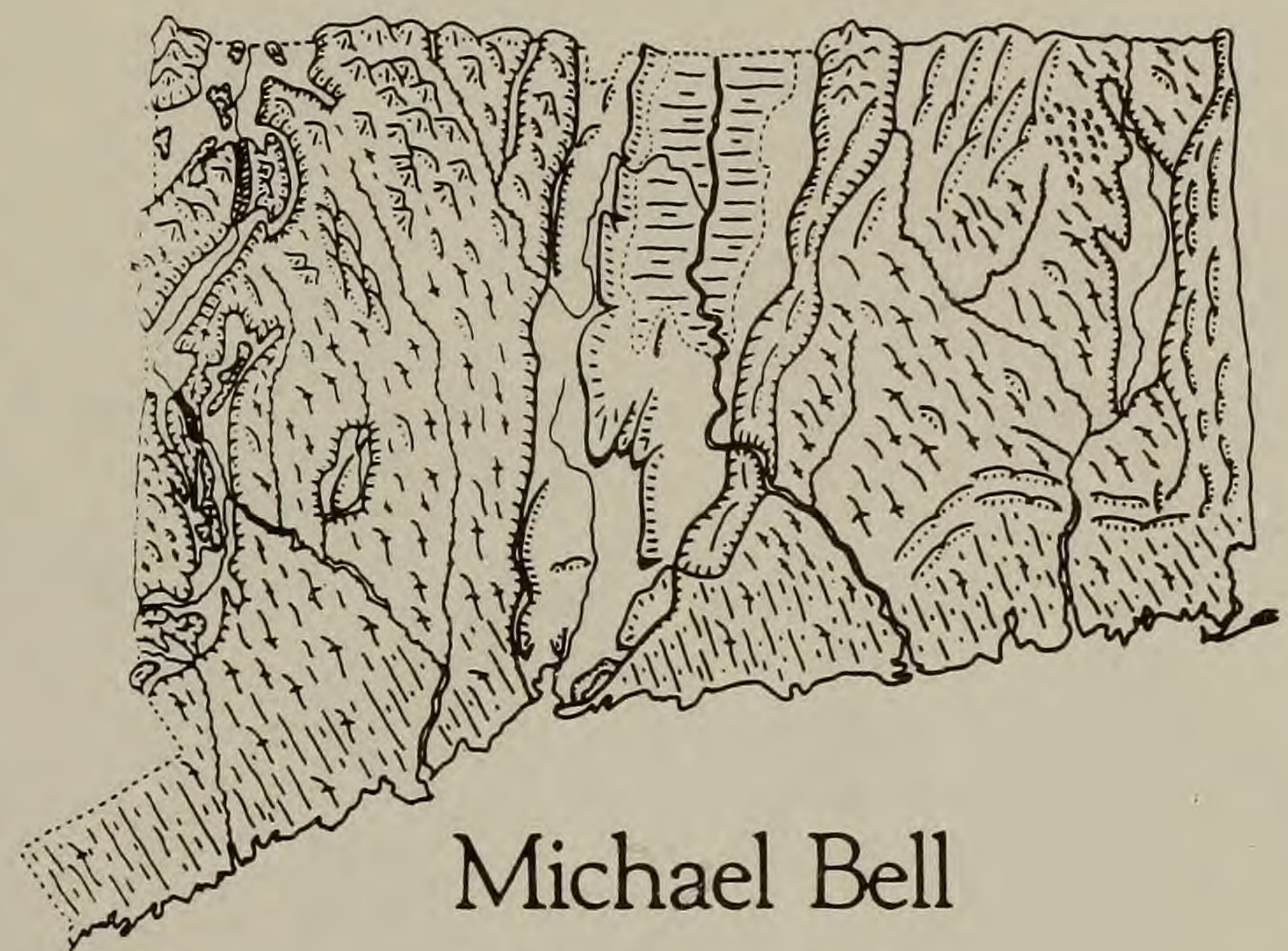

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